A BREEDING EXPERIMENT WITH THE SMALL COPPER BUTTERFLY, *LYCAENA PHLAEAS* (L.) (LEPIDOPTERA: LYCAENIDAE)

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In his classic book on butterflies, Ford (1945) discussed a hypothetical case in which the aberration *obsoleta* (a known recessive) and the aberration *alba* (which he considered also probably a recessive) were mated together and then inbred to give, in the F_2 generation, wild-type, *obsoleta*, *alba* and the double recessive *obsoleta* + *alba* in a 9 : 3 : 3 : 1 ratio.

So far as I am aware, no-one has been able to perform such an experiment. In 1989 and again in 1991, I was able to carry out some small-scale breeding experiments that bear some resemblance to Ford's case, using wild females caught in the Wokingham area of Berkshire.

In two small-scale breeding experiments on *Lycaena phlaeas*, the aberration *obsoleta* appeared to act as an incomplete recessive to the wild type. The aberration *radiata* appeared to be distinct from *obsoleta*, although their heterozygotes, appearing dissimilar, are both referable to *partimauroradiata*. The double recessive *pallidula* + *radiata* was obtained.

NOMENCLATURE

Since the strict rules on priority in zoological nomenclature are no longer enforced at the level of subspecific aberrations, some names that are commonly used and which are reasonably descriptive of the aberrations are used. These are as follows:

ab. *obsoleta* Tutt—with the hind-wing copper band absent (although some traces can usually be detected in the interneural spaces between the veins).

ab. *radiata* Tutt—with the hind-wing copper band replaced by thin lines on the nervures.

ab. *partimauroradiata*—with the hind-wing copper band broken up, but not as extreme as *radiata*.

ab. *alba* Tutt—with the copper colour of the fore and hind wings replaced with silver.

ab. *pallidula* Leeds—with the copper colour of the fore and hind wings replaced by a brassy or cream colour.

ab. *subradiata* Tutt—with fine copper-coloured rays extending along the nervures inwards from the hind-wing copper band.

ab. *auronitens* Schultz—with a copper suffusion on that part of the hind wing which is normally dark brown, sometimes incorporating the ab. *subradiata*.

METHODS

The 1989 experiment

A female ab. *partimauroradiata* (as in Plate I, Figure 1) was captured at Wokingham, Berks., in May 1989, and when she had laid about 50 eggs in captivity she was released at the point of capture. An F_1, but no F_2, was raised (Robertson, 1990).

The 1991 experiment

A female showing, rather weakly, the characters *partimauroradiata, subradiata* and *auronitens* was captured, in rather worn condition, at Finchampstead, Berks., in June 1991 (Plate I, Figure 1). She laid a small number of eggs and died a few days later. An F_1 of seven adults was reared and one mating followed. An F_2 was reared, and the numbers of the different forms of adults were recorded. No matings were obtained in this generation (Robertson, 1992).

RESULTS

The 1989 experiment

The 39 F_1 adult offspring reared from the captured female *partimauroradiata* showed a range of variation from wild-type (with fully developed hind-wing bands) to *obsoleta* (Plate I, Figures 2–4). Twenty were referable to *obsoleta*, but all had traces of copper remaining on the hind wings. However, this was in the interneural spaces rather than on the nervures, which distinguishes it from ab. *radiata*. Most of the remaining 19 butterflies showed more or less reduction or breaking up of the bands (ab. *partimauroradiata*); a few showed wild-type markings.

The 1991 experiment

The F_1 from the P_1 female *partimauroradiata* + *subradiata* + *auronitens* consisted of 4 male and 3 female wild-type adults. The F_2 from the single mating consisted of 37 butterflies, none of which showed the *subradiata* or *auronitens* characters that were present in the P_1 female. However, two forms which had not been detected in the P_1 or F_1 occurred, separately and in combination. These were *radiata* (Plate I, Figure 8) and *pallidula* (Plate I, Figures 9–12). Forms with hind-wing bands varied from wild-type through *partimauroradiata* and could not be classified as such with certainty, so were scored as 'with bands'. Although variable, *pallidula* and normal copper colour were reasonably distinguishable and were scored accordingly. The *radiata* form was clearly distinguishable and differed from the *obsoleta* forms of the 1989 experiment in that it did not have any interneural traces of copper. Males and females were in about equal numbers and occurred in both varietal forms. The results of the 1991 experiment are summarized in Table 1.

Table 1. The phenotypes of the F2 of the 1991 experiment with *Lycaena phlaeas*

	Ground colour		
	Copper	Brassy	Total
Hindwing band			
with bands	20	8	28
bands replaced by rays	6	3	9
Total	26	11	37

The ratio 20 : 8 : 6 : 3 is achieved. This concurs with the predicted ratio of 9 : 3 : 3 : 1 (as 8.65 : 3.46 : 2.59 : 1.30). There is no statistical difference, $\chi 2$ (3 degrees of freedom) = 0.52, $0.95 > P > 0.8$.

Discussion

Taken together, the two experiments suggest that *obsoleta* and *radiata* are distinct from one another. In their heterozygous state, both are incomplete recessives and are referable to *partimauroradiata* but still differ (Plate I, Figures 1 and 7), so this name can represent two different mutations.

The 1989 experiment gave an almost exact 1 : 1 ratio for *obsoleta* to 'with bands' (*partimauroradiata* + wild-type) suggesting that the expression of *obsoleta* in the heterozygote is variable, and that the P_1 female was heterozygous for *obsoleta* and had mated in the wild with a homozygous male *obsoleta*. The P_1 cross would be represented by:

$$Oo \times oo$$

The F_1 would then be 50% Oo and 50% oo, conforming to the result obtained.

An alternative explanation for the F_1 in the 1989 experiment is that not one but two gene complexes were involved, with *obsoleta* dominant to *radiata* and both recessive to the wild-type. The cross to lead to the F_1 would be:

$$RrOo \times RRoo$$

The F_1 would have the following genetic make-up:

RROo RROo RrOo RrOo
RRoo RRoo Rroo Rroo

The gene combinations shown in the upper line would give wild-type and *partimauroradiata*, and those of the lower line *obsoleta* (o being dominant over r), again a 1 : 1 ratio as obtained in the experiment.

As neither *obsoleta* nor *radiata* are common, their occurrence together is not particularly likely, and the single-gene mechanism is perhaps the more probable one.

The 1991 experiment resembles that of Ford (1945) in some respects, except that it involves *pallidula* and *radiata* rather than the more extreme *alba* and *obsoleta* which Ford discussed.

To get the results obtained, the cross to give the F_1 must have been: RrPp × RRPP or RrPP × RRpp.

The following genetic make-ups, for example, could be present in the F_1: RrPP RrPp RRPp RRPP

In whatever combinations of R and P, the result would still produce all wild-type (apart perhaps for some *partimauroradiata*) and to get the result obtained in the F_2 generation the F_1 cross would be: RrPp × RrPp. It was fortunate that with only seven butterflies in the F_1 this mating must have taken place.

The complete genetic make-up of the F_2 would be as follows:

RRPP RrPP RrPP rrPP
RRPp RrPp RrPp rrPp
RRPp RrPp RrPp rrPp
RRpp Rrpp Rrpp rrpp

Examination of this make-up reveals a 9 : 3 : 3 : 1 ratio for wild-type: *pallidula* : *radiata* : *pallidula* + *radiata*.

It has been shown that both *obsoleta* and *radiata* are incomplete recessives, and that even in the heterozygous condition remain distinct. The brassy coloured *pallidula* is a complete recessive and is probably not the heterozygote of the silvery *alba*. The double recessive of *radiata* with *pallidula* indicates that these are non-linked genetically.

The forms *auronitens* and *subradiata*, present rather weakly in the P_1 of the 1991 experiment, did not appear in the F_1 or F_2, and either are not controlled in a simple Mendelian fashion, or, more probably, were lost when only one mating was obtained from the very small F_1 reared.

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REVIEW

Entomological bygones or historical entomological collecting equipment and associated memorabilia by J. M. Chalmers-Hunt. *Arch. Nat. Hist.* 1994; **21**: 357–378—Being asked to review for this journal a paper appearing in another journal, particularly one which was essentially a catalogue of items, has presented quite a reasonable challenge. Nevertheless, the equipment and other memorabilia associated with field entomology is a much neglected subject and, were it not for the genuine passions of gentlemen such as my friend Michael Chalmers-Hunt, important historical material such as this may well be lost for ever, save within the pages of ancient, dusty entomological books. One wonders how many of today's entomologists have actually heard of a forceps net, let alone know what one looks like or how to use it. And who today could afford, or would even wish to use, a hand-crafted mahogany and brass killing bottle?

The paper catalogues some 200 items of entomological memorabilia in the Chalmers-Hunt collection. They range from nets and beating trays to pooters, collecting boxes, setting boards and even curious light sources for attracting moths on dark nights. Who in his right mind would, today, wander around the local woods with a "bull's-eye oil-burning lantern" and seriously hope for a large "bag" of moths? Ah . . . those were the days (so they tell me!).

Chalmers-Hunt is one of a diminishing breed of true collectors. Not only does he amass the objects of his desire, but also books, journals, manuscript catalogues, diaries and notebooks, equipment and, indeed, absolutely anything else that is in any way associated with his chosen entomological subject. In the Chalmers-Hunt collection, now housed at the British Museum (Natural History) [which name I shall continue to use until it is formally altered by Act of Parliament] we have, probably, the most comprehensive collection of entomological equipment. Chalmers-Hunt is to be congratulated not only for accumulating the material that goes to form his collection, but also for cataloguing it and having the good sense to ensure its survival by gifting it to a national, rather than a local, museum.

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